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## The caribbean information system : from satellite to decision makers

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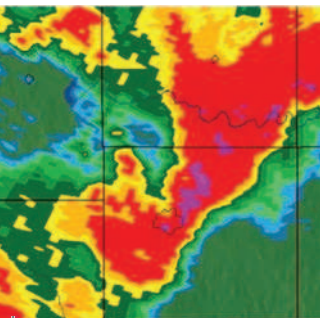
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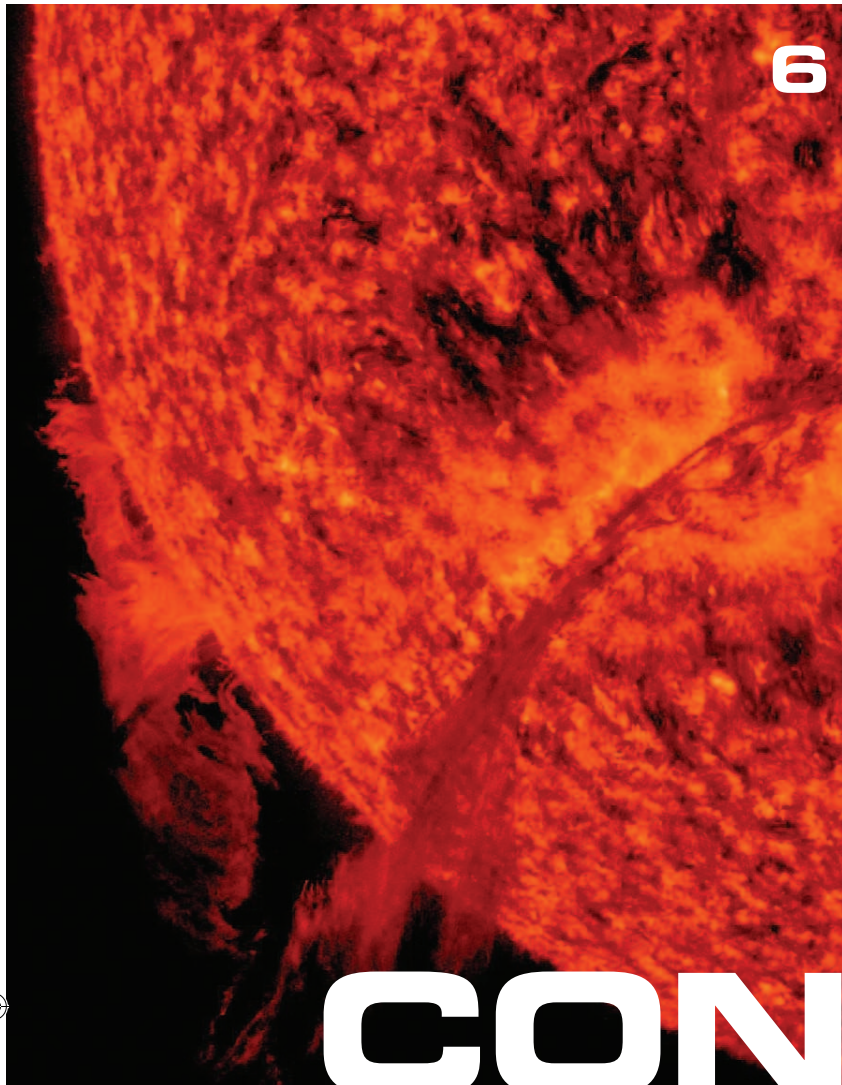


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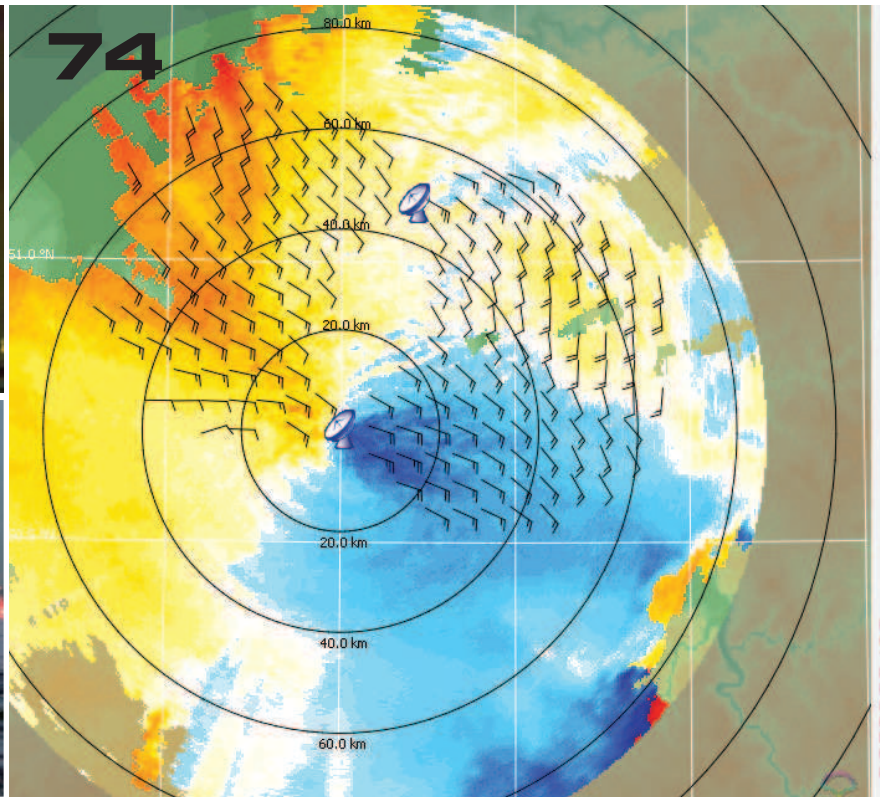
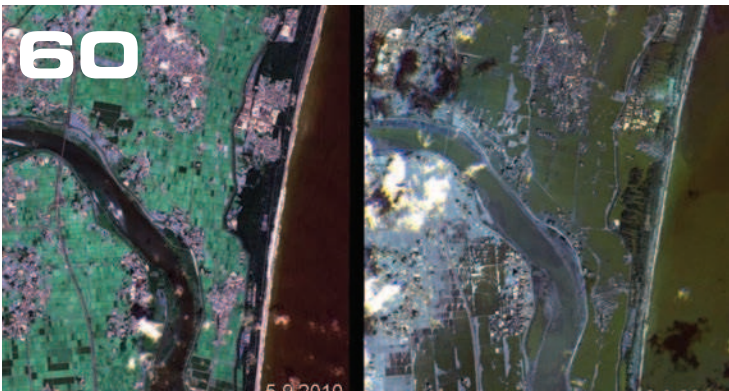
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# UNIQUE MARTINIQUE

## The Caribbean information system: from satellite to decision makers

The INTERREG Caribbean IV program recommends the valorization and protection of the region's environmental core, through collaborative and sustainable management of resources. It uses Martinique as the test case

**T**he French territories of Saint-Martin, Saint-Barthélemy, Guadeloupe, and Martinique, and the member states of the Organization of Eastern Caribbean States are part of a geographic continuum that can easily be identified through its similar landscapes, climates, and natural resources and also through the environmental degradation the states have to face, caused by human activity (pollution and deterioration of ecosystems and habitats), natural hazards, and climate change including sea level rise.

Therefore the islands of the Lesser Antilles are faced with an important developmental and environmental challenge, which could be easily summarized as a struggle for balance

### The ultimate objective

The Caribsat project, funded by the European Commission, aims to conceive and implement within the Lesser Antilles an instrument to achieve sound environmental management and sustainable development based on an online geographic atlas supplied by the acquisition and analysis of satellite images, associated with a knowledge database and customized decision tools.

More specifically, Caribsat is targeted toward the preservation of biodiversity in land and sea, management of the risks related to natural disasters, and mitigation of climate-change impacts.

The project was launched within the framework of the INTERREG IV Caribbean Programme. The Caribsat

processes by developing customized tools for the assessment, management, and physical planning of the target territories; train students and young experts; and create a vehicle for collaboration between public and private organizations and for cooperation between the territories of the Lesser Antilles archipelago, and exchange between the area of the Caribbean and the European Union.

Public institutions, NGOs, and private companies of Martinique, Guadeloupe, French Guiana, and all other partner countries of the Lesser Antilles are involved in environmental management, preservation of natural land and sea areas, and sustainable management of natural resources.

## “The global change currently observed generates an intensification of the coastal erosion phenomena”

between preservation of biodiversity and entropic pressure induced by economic and social growth, in order to achieve eco-development.

To achieve their eco-development, the Caribbean islands must address numerous challenges: protection of mangroves and wetlands; sustainable mobilization use of water resources; control of domestic, agricultural, and industrial pollutions; control of land erosion and hyper sedimentation; management of risks induced by natural disasters; and adaptation of the Caribbean territories to climate change.

Project is led by IRD, Institut de recherche pour le développement (UMR ESPACE-Dev, IRD Martinique Center) in deep collaboration with the French University of Antilles and Guiana.

### The strategy

The strategy of the Caribsat project is based on implementation on the island of Martinique using a technical platform for interdisciplinary scientific research. This is in order to develop advanced concepts and methodologies to process satellite images and spatialized data and information. It also aims to support policy-making

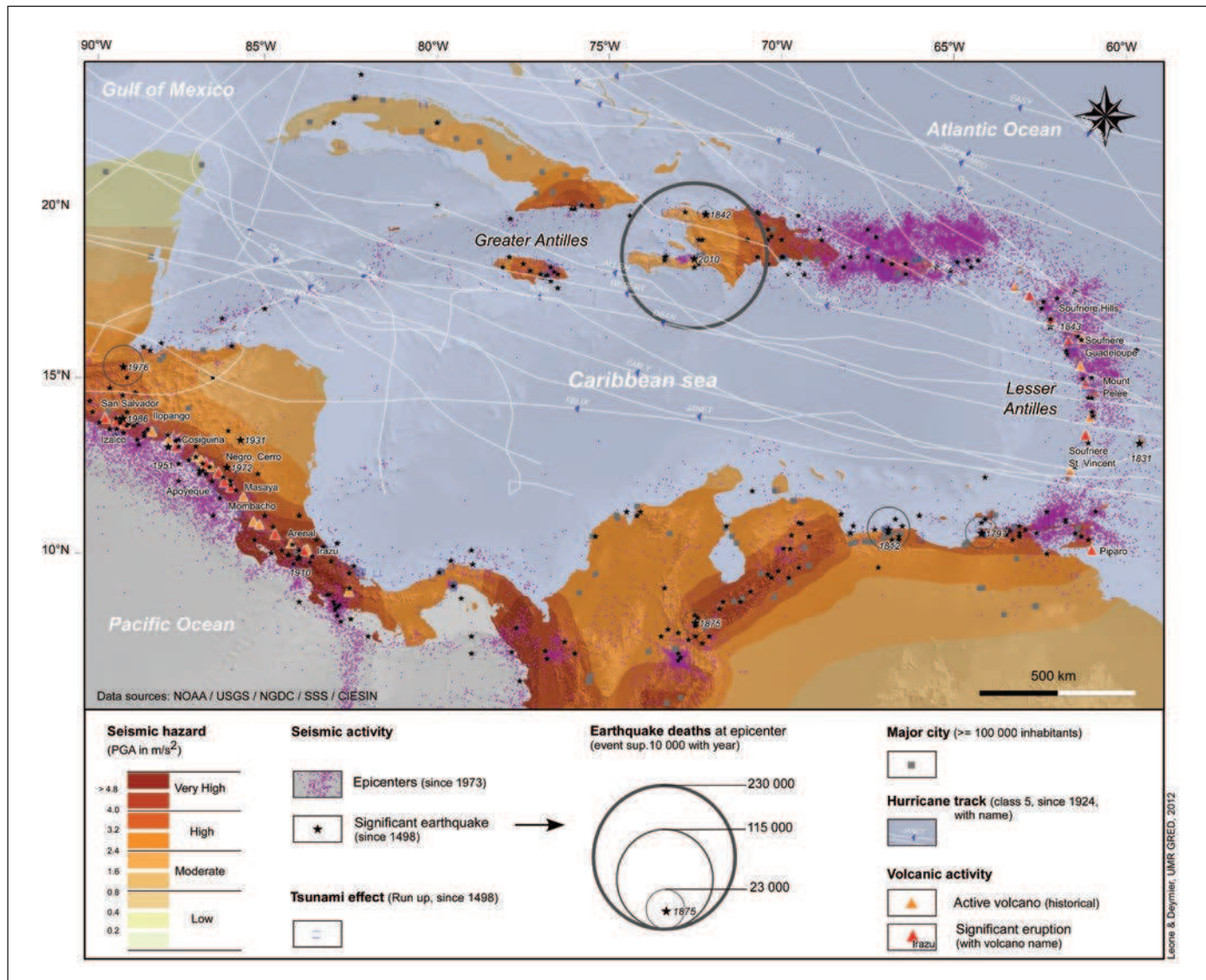
### Achievements and perspectives

The backbone of the project is the implementation on an island scale, such as the Lesser Antilles, of an environmental information system based on regional land use and land cover mapping, digital elevation models, climatic, and all physical data available.

This land use and land cover mapping with associated databases is the first initiative toward a regional approach for environment monitoring using remote sensing data.

It is obvious that the existing data on a global scale, such as USGS MODIS Global Land Cover Mapping, Global land cover Facility, GlobCover, etc, does not allow proper regional analysis because the scale is too large. On the other hand, data collected at local scale (national land use/land cover map, vegetation map, agricultural map, etc)





is not homogeneous and cannot be compared from one island to another. Only the regional scale is appropriate for comparison of the status of the environment on one date or to monitor its evolution in the relevant area.

The map made for each island from Trinidad and Tobago to the British Virgin Islands is based on the processing of SPOT 5 images, 10m resolution, collected by the SEAS Spot-Image station managed by the IRD center in French Guiana.

On these very highly fragmented islands, two methods have been tested: pixel-based analysis and object-orientated classification using e-cognition software. The results show that the pixel-based classification made by using ENVI software is easily reproducible on another image. However, comparison of the confusion matrix between the two types of classification shows better results with the

object-orientated approach for discrimination between barren land and urban, and the detection of agricultural land. In the end, seven classes of land use/land cover have been defined.

### Webmapping system

The Caribsat webmapping displays the land use and land cover maps associated with digital elevation models, climate rainfall variability, administrative areas, roads, and catchments limits.

Work has been conducted within the Caribsat project to apply remote sensing on the assessment of hurricane impacts on mangrove and early vegetation recovery. Hurricane Dean (2007) severely impacted mangrove forests along the Bay of Fort-de-France (Martinique, FWI). This event provided an opportunity to assess mangrove resistance and early recovery

### Multi-risks map of Caribbean - Léone & Deymier - CARIBSAT

following hurricane disturbance, both of these processes being poorly understood in mangroves worldwide. For this purpose, three sequential maps of mangrove vegetation around the bay have been implemented by means of satellite image analyses (IKONOS 2006 and 2008, SPOT 5 2006 and 2010) and field measurements. This work in Martinique will lead to the implementation of a mangrove observatory on a regional scale, based on remote-sensing survey and vegetation monitoring.

### Implementation of the SPI

Concerning the effects of climate changes on water resources, it is proposed to implement the Standardized Precipitation

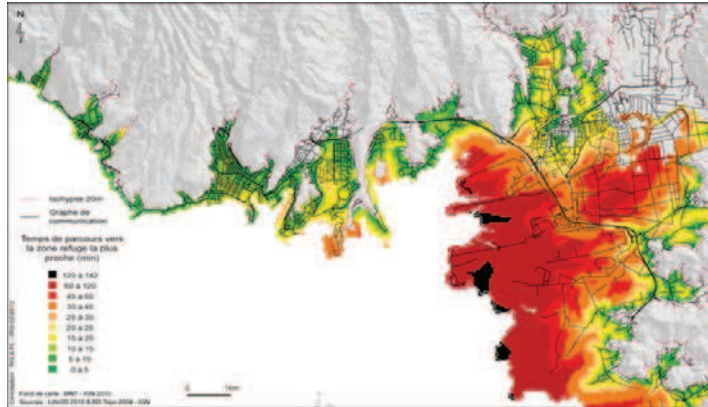
Index (SPI) for monitoring drought in some of the Lesser Antilles islands. The SPI is a drought index based only on precipitation. It can be used to monitor conditions on a variety of timescales to produce drought maps. The Interpolated WorldClim data will be used to set up global gridded climate layers with a spatial resolution of 1km<sup>2</sup>. Collaboration will be established with regional initiatives (Carib-HYCOS project) and international centers such as CIMH (Caribbean Institute for Meteorology and Hydrology).

Inside this framework, a monitoring network for littoral dynamics under the guise of hurricane events has been reinforced and established.

The global change currently observed generates an intensification of the coastal erosion phenomena and, probably, an increase in frequency and intensity of paroxysmal weather events and, simultaneously, the rise of sea levels and expected disappearance of coral reef barriers.

These phenomena are exacerbated on tropical coasts hosting large coastal populations, and therefore render the coasts and their societies very vulnerable. Since 2003, a monitoring network of the dynamics of sandy beaches has been in operation in several tropical sites: Martinique, Guadeloupe, Saint-Martin and Saint-Barthélemy (French West Indies), Tahiti and Moorea (French Polynesia), Scattered Island and Mayotte (Mozambique Channel).

The objective of this network is to observe, supervise, and characterize the rates/rhythms and mechanisms of the evolution, adaptation, and impact strength of various types of tropical beaches facing the paroxysmal weather-marine events to which they are subjected (cyclones, storms, surges, and strong swells), in order to develop and implement appropriate defense strategies and/or adaptation.



**Map of flooding risks and ground movement risks for existing buildings**

### Land management practices

Understanding urban sprawl processes is a key issue for more efficient land management practices and better assessment of the vulnerability of the settlements. In this context, an urban classification methodology has been developed using the island of Martinique as a case study.

It is applied to different timescales, and leads to various scenarios of evolution. This methodology, based on spatial analysis tools, aims at characterizing urbanization through its various components, its restraining factors, and the parameters that could encourage its expansion. This modeling takes into account not only the elements involved in urban structures and processes, but also the interactions between them. The systemic model is a base for producing a multi-criteria analysis with cartographical outputs, in order to create an urban classification: dense urban zones, non-urban zones, diffuse built areas, etc.

Various timescales are used during this analysis so that a diachronic vision of urban evolution is realized, and potential source spots are identified. In this way, Caribsat proposes some prospective scenarios that should show areas subjected to stronger

urban pressure. Other application areas will be chosen in the Caribbean region, through the improvement of a regional cooperation process.

The Caribbean basin is exposed to many natural disasters. It concentrates many natural hazards (seismicity, volcanism, hurricanes, floods, tsunamis, landslides, etc) and important human and strategic stakes. For these reasons it is an area of interest for assessing risk by integrating and mapping its many components: hazards, vulnerabilities, and socioeconomic stakes.

The Caribsat project team and the research laboratory GRED (University of Montpellier, France) have combined GIS data and geo-indicators of natural risks in the Caribbean basin in order to offer a tool for comparative diagnosis and preventive information on a regional scale, which takes the form of a multinatural hazards GIS. This international geo-referenced database harmonizes multiple sources of historical, scientific, and geographical information structured with the same digital format. GIS Caribsat suggests many applications in the field of geographical risk studies, pedagogy (dynamic atlas online), prevention, and decision support. It is useful to develop several families of geo-risk and natural disasters indicators: natural hazards activity, human and socioeconomic impacts, and levels of exposure.

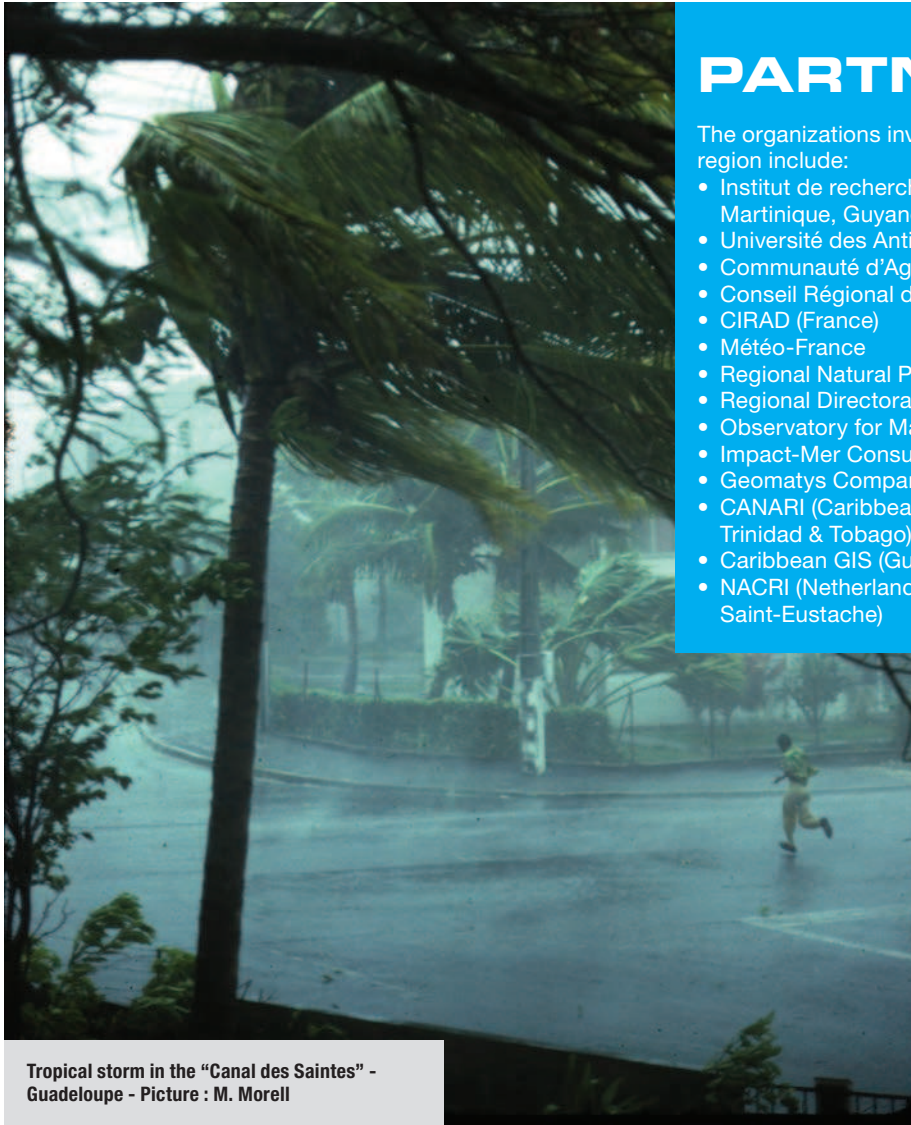
### Regional danger

The risk of tsunami threatens the whole Caribbean coastline, particularly the Lesser Antilles. Its origin can be seismic, volcanic, or submarine landslides. In view of this high threat, the only effective protection is a preventive and organized evacuation of coastal populations. This requires a performing regional warning system and modeling of tsunami propagations to be designed, in order to prepare people to evacuate and to draw up local and regional



**Impact of sea rising in Guadeloupe - Picture : M. Morell**





Tropical storm in the "Canal des Saintes" - Guadeloupe - Picture : M. Morell

## PARTNERS

The organizations involved in the project throughout the region include:

- Institut de recherche pour le développement (IRD – Martinique, Guyane)
- Université des Antilles et de la Guyane (UAG)
- Communauté d'Agglomération de l'Espace Sud Martinique
- Conseil Régional de la Martinique
- CIRAD (France)
- Météo-France
- Regional Natural Park of Martinique
- Regional Directorate for Physical Planning and Environment
- Observatory for Marine Environment in Martinique
- Impact-Mer Consulting (Martinique)
- Geomatys Company (France)
- CANARI (Caribbean Natural Resources Institute; Trinidad & Tobago)
- Caribbean GIS (Guiana)
- NACRI (Netherlands Antilles Coral Reef Initiative; Saint-Eustache)

at 10x10m resolution provided by the SEAS Guyane satellite reception antenna have been used for land use mapping over the entire Lesser Antilles, with a specific focus on the small islands. A set of ad-hoc indicators and statistical texture indicators have been developed and combined with GIS modeling based on the Global Island Database (GID, UNEP World Conservation Monitoring Centre) to prioritize further field surveys and conservation actions on a regional scale. Strategic plans for island biodiversity issues on regional and global scales is emphasized by the Global Island Partnership (GLISPA, CBD), which tends to give priority to the ecosystem approach to conservation. Such a task requires efficient tools and methods such as remote sensing and GIS modeling to survey large areas.

In conclusion, the achievements of the Caribsat project are focused on the use of remote sensing technologies applied to the automatic detection of changes impacting agriculture production, forest cover, mangroves, littoral zones, beaches, coral reefs, etc.

The data and tools provide the basis for monitoring the environment of the Lesser Islands in the wider perspective of the implementation of an Environmental Observatory of Caribbean islands in connection with other ongoing initiatives and projects in the area. ■

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emergency plans.

The first models of tsunami propagation give travel times of a few minutes to Martinique for the closest seismic sources. To maximize an evacuation plan, the Caribsat team assesses the number of exposed people, possible evacuation routes, and safe areas, and set the time to evacuate all people at risk. But there could still be crucial missing information for the emergency plans of the French Antilles (Martinique and Guadeloupe).

A GIS-based macro-simulation of evacuation for the whole of Martinique has been developed. It is based on the creation of databases on the human stakes, the constitution of connected networks of roads, the location of potential refuge areas, and the setting of evacuation speed by foot according to the slope. Evacuation routes are calculated using Dijkstra's algorithm (1959),

which gives the shortest path between coastal and refuge areas.

The first results enable mapping of the theoretical time to secure the exposed population, and also a comparison of these results with the arrival time of a local tsunami. Further improvements of the model are scheduled to make it effective in a crisis management context.

One of the Caribsat project actions focuses on a scientific asset for potential biodiversity estimates on a regional scale. Based on the survey of the small islands in the range 0.5-10km<sup>2</sup> within the Lesser Antilles, this amounts to about 200 islands for a total area of 184km<sup>2</sup>. These are good candidates for the 'Lazarus effect' for species that have been eradicated from the mainland. There are many examples of this throughout the world, such as the Bermuda Petrel (*Pterodroma cahow*) rediscovered on a tiny rock. The SPOT 5 images